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Stock Assessment of Indian Scad, Decapterus Russelli in Pakistani Marine Waters and Its Impact on the National Economy

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Abstract

The stock assessment, of Indian scad *Decapterus russelli* (Ruppell, 1830) from the northern Arabian Sea in Pakistan was evaluated. The samples of Indian scad (13300 specimens), ranging from 1-31 cm (FL) and 1-400 g (TW) were collected from the commercial fish landing center located at Karachi harbor. The parameters of fish length-weight relationship were calculated from the aggregated data as a=0.0323, b=2.66 with R2=0.954, indicating slightly negative allometric growth between the relationship. The length frequency samples from September 2013 to November 2014 was analyzed using FISAT II software, including the ELEFAN-I method. The growth parameters obtained using ELEFAN I was: L_∞=32.55 cm, K=0.750 per year, t_0=-0.678 with an Rn value of 0.220. Natural, total and fishing mortality M=1.42 per year, Z=3.84 per year at CI of 95% (CI=3.11-4.58) where F=2.422 per year and exploitation relation E=0.630 were obtained. Growth performance indices for L_∞ and W_∞ were performed using FiSAT-II program in order to estimate the limit and target reference points of stock exploitation were, Φ'=2.900 per year and Φ=0.170 per year, respectively. The results revealed that the natural fishing level of D. russelli (1.42 per year) was higher than the biological reference points $F_{0.1}$ (0.85) and F_{max} (0.9). Moreover the proportion of current mortality $F_{current}$ obtained was 0.630, representing that stock of *D. russelli* as highly exploited.It can be concluded from this study that the population parameters and the stock of *D. russelli* showed overexploitation in the northern parts of the Arabian Sea coast of Pakistan.

Keywords: Indian scad; Economic management; Stock assessment; Exploitation status; Pakistan

Introduction

Fish is one of the important sources of nutrition providing high quality proteins and a wide variety of essential micro nutrients, trace minerals, vitamins and fatty acids, even commonly utilized as healthy foodstuff around the globe [1]. There are more than 20,000 different fish species in the world and their utilization is more dependent on the availability in the local presence [2]. In addition, fish is also regarded as one of the widely consumed food in the coastal cities globally [3]. Seafood export play a vital role in in Pakistan's national economy. The exports of fish and fish preparations have been decreased by 7.30 percent in quantity and in value have been decreased by 5.28 percent during 2015. Gross Domestic Product (GDP) growth through this sector recorded in Pakistan was 2.9 and 2.7 during 2014 and 2015, respectively. Although Fisheries share in GDP is very little but it adds substantially to the national income through export earnings, [4]. One way to increase the role of fisheries in national GDP is to put a stop to over-exploitation of fish stocks. Thus the country has the potential to become a major producer of seafood, not only for local consumption but for the global market as well. Currently, about 400,000 people are directly engaged in fishing in Pakistan and another 600,000 in the ancillary industries, Ebrahim, [5]. Pakistan fisheries sector has an important implication towards other sectors to reduce the ongoing pressure on demand of food [6]. In the coastal regions of Sindh and Baluchistan province, at least 90% of inhabitants are dependent on the activities related to fisheries and other fishing activities, Siddiqi [7]. Besides ocean, Pakistan is blessed with a large number of aquatic resources, including freshwater lakes, reservoirs, ponds, natural depressions, irrigation canals, waterlogged areas, rivers, and streams, contains a wide variety of commercial fish and shell-fish species [8]. The Indian scad, *Decapterus russelli* belonging to Carangidae family is a benthopelagic marine species [9]. *Decapterus russelli* is considered as a majorly important fishery resource and locally named as “seem” in the regions of Sindh and Balochistan province of Pakistan [10]. This is the most common *Decapterus* species in the western Indian Ocean. The fish forms large schools in water not exceeding 100 meters depth. *Decapterus* species reaches maturity during the first year of life, at about 10 cm total length and feeds on small planktonic invertebrates. It reaches at 35 cm (FL) and common length is 20 cm. *Decapterus* species is commonly found in large quantities in the local markets of Pakistan and is very popular in other Asian countries, Bianchi [10]. It is one of the main coastal demersal target species of commercial interest in the Northern Arabian Sea particularly in Pakistan, Bianchi [10]. This specie is most common and exclusively caught by purse seines and trawls operating in the shelf of the Arabian coast in muddy and sandy bottoms, Bianchi [10]. Generally, it is sold either fresh, or dried and sometimes salted as well as marketed as frozen and canned, Frimodt [11]. To best of our knowledge, least studies are carried out for stock assessment of this species in Pakistani marine waters. Although various studies regarding its biology, population dynamics, and stock assessment have been accounted for Indian scad fish species from all over the world mostly from Indian waters [12-14]. Despite of its economic importance, no effort was made to assess the fishery, biology and stock characteristics of Indian scad from Pakistani marine waters. Therefore, present research carried out for the first time towards evaluation of population and stock assessment parameters for *D. russelli* conducted from the Arabian Sea coast of Pakistan.

Growth, mortality, and recruitment parameters are essential for the assessment and management of fish stocks. Since these parameters determine the catch, the annual amount of fish exploited in fishery resources. Recently, numbers of research reports were conducted on the number of fish species and suggest some management steps to maintain the fish stock in northern Arabian Sea using FiSAT package [6,15-20]. This study is aimed to assess the impact of fishing pressure on fisheries resources and annual stocks of *D. russelli* along the northern Arabian Sea of Pakistan. Thus, our study is mainly focused on the annual stock, population structure and dynamics, growth, mortality, biomass and the production of Indian scads. The length frequency distribution data mainly used to determine the stock status to regulate the fishing efforts to maintain the fish stock. The output of population dynamics gives indications on the level of exploitation and the indicators of declining stocks. Hence, the generated information could be used as an input in ecosystem-based fisheries management models in Pakistani waters, which was not available previously. The present study will contribute to know the stock status of *D. russelli* fishery from Pakistani waters and suggest a strategy for better management.

Material and Methods

Data collection and sampling

Total of 13300 individual samples (both sexes combined) of *D. russelli* were obtained monthly from September 2013 to November 2014 at the Karachi fish harbor, Sindh province (Figure 1). The coastline of Pakistan is about 1120 km, which represents 772 km of Baluchistan and Makran coast to the Iranian border and 348 km measures the Sindh coast that extends to the Indian border (Figure 1) [21]. The length frequency and length weight were measured for further analysis. The total length was measured in cm and weight was taken in grams (g).

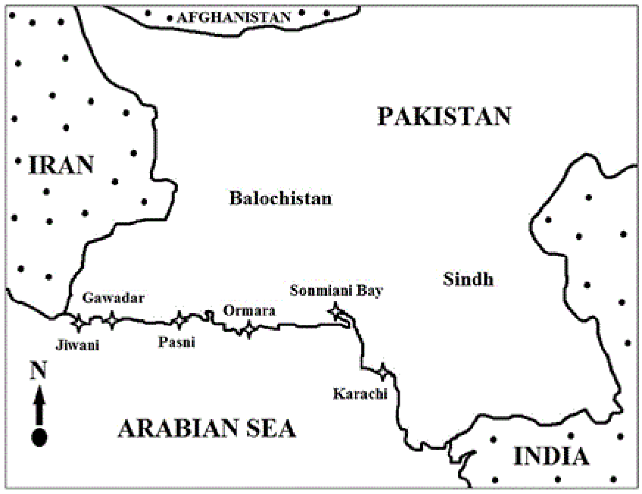

Figure 1: Map of Pakistan.

Data analysis

The pooled length frequency distribution data of both sexes combined was prepared on the monthly basis using FiSAT-II (FAO ICLARM stock assessment tool) computer software package [22]. Then the length data was merged and grouped into 1 cm class intervals in order to estimate the parameters of growth, mortality, growth performance index, yield per recruit and biological reference points, methods available in FiSAT package. Biological reference points are widely used for the management and conservation of fisheries resources nowadays, Haddon [23]. Biological reference points (BRPs) have been defined as the level of fishing mortality and/or of biomass.

Length-Weight Relationship

The length weight relationship data of *D. russelli* was calculated by the power function equation

W=aLb [24,25]

where "W" is the total weight (g),

"L" is the total length (cm),

"a" is the intercept

"b" is the slope.

Growth parameters

For the preliminary estimations of asymptotic length (L_∞) and growth constant (K) the length frequency distribution data was used in ELEFAN-I. The growth coefficient of *D. russelli* was estimated by fitting the von Bertalanffy growth function (VBGF). The van Bertalanffy growth equation was defined by Haddon [23] as:

$$L_t = L_\infty\left(1 - \exp\left(-K\left[t - t_0\right]\right)\right)$$

Where, L_t is the length at the predicted time t, L_∞ is the asymptotic length, K was the growth coefficient and t_0 is the hypothetical age or time where length was equal to zero. The value of t_0 is estimated by the empirical formula by, Pauly [26] as:

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$$\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L_\infty - 1.038 \log_{10} K$$

Mortalities rates

The length of the converted catch curve [26] was used to estimate instantaneous total mortality (Z), natural mortality (M) and fishing mortality (F) by using FiSAT package. The merged monthly data of length frequency distribution was arranged to obtain catch curve and natural logarithm (ln) of the number of individuals with respect to the age group (N) were designed against the results of their relative age (t), Pauly [26]. In order to obtain independent estimates of natural mortality (M), the subsequent formula of Pauly [27] was used as:

$$\text{Log}_{10} M = 0.0066 - 0.279 \log_{10} L_\infty + 0.654 \log_{10} K + 0.4634 \log_{10} T$$

The annual average sea surface temperature (SST) was taken as 27°C, because it was the average monthly water temperature. Fishing mortality (F) was derived by subtracting Z from M. The ratio F/Z can also be used to obtain the exploitation ratio (E).

Biological reference points

The biological reference points (BRP) was estimated by, Gulland [28] method, according to the optimum fishing mortality rate F_{opt}=0.5M. The most well-known biological reference points are $F_{0.1}$ and F_{max}, they are commonly used for fisheries management [29]. The target biological reference point F_{max} is considered as a function of fishing mortality (F) for a definite exploitation pattern against the maximum value of yield per recruit (Y/P).

Beverton Holt yield recruit model

The relative yield per recruitment is analyzed by the model of Beverton-Holt yield per recruit with the knife edge selection in FiSAT-II. Yield per recruit was estimated by [30] model with the formula as under:

$$Y_w/R = FW_\infty e^{-M(t_c - t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c - t_0)}}{F + M + nK} (1 - e^{-(F+M+nK)(t_\lambda - t_c)})$$

where, Y_W/R is yield per recruit, t_c is the average age of first capture, t_r is the age of recruitment, t_λ is the asymptotical ages, Q_n was the constant and equal to 1, -3,3 and -1 when n is 0,1, 2 and 3 correspondingly [31].

Growth performance index

The growth performance index (Φ') helps to explain the characteristics of the different ecosystems of the stock or housing of the different population of the environment [32]. Growth performance index is conducive in both movement (K and L_∞) between species and growth. To compare the growth, we used the phi prime (Φ') performance index of overall growth of Pauly and Munro [33]. In this model, the calculated values of L_∞ and K were used to estimate the asymptotic length (L_∞) and asymptotic weight (W_∞) from the routine below of the equation [33]:

$$\Phi' = \log_{10} K + 2 \log_{10} L_\infty \quad \text{and} \quad \Phi = \log_{10} K + 2 \div 3 \log_{10} W_\infty$$

Results

Length-weight relationship

Total of 997 (both sexes male and female) pairs of *D. russelli* species length and weight were observed in this study. The length range were from 1 to 31 cm (FL), the total weight ranged from 0.5 to 388 g. The foremost length ranged of *D .russelli* were from 9 to 18 cm FL (Figures 2 and 3). The average length and weight is 14.048 (± 4.775) cm (FL) and 99.082 (± 44.784) g (TW) correspondingly (Table 1). The combination of total length-weight relationship of both sexes was calculated as

$$W = 0.0323\, L^{2.66}\ (R^2 = 0.954),\ n = 997$$

	2013			2014						
ML	**Sep.**	**Oct.**	**Nov.**	**Feb.**	**Mar.**	**Apr.**	**June**	**Aug.**	**Oct.**	**Nov.**
1				1		50			40	
2				1	1	102			123	3
3				10	1	100			119	41
4				8	1	80			97	113
5				20	1	65	1		85	169
6				25	3	55	1		55	157
7	5	3		22	19	3	22		3	134
8	15	34	20	15	59	1	73		1	85

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9	170	488	300	8	37	3	45	1	3	90
10	380	1493	800	8	13	1	26	1	1	117
11	500	878	425	7	11	5	16	1	5	67
12	90	86	40	5	8	1	21	1	1	211
13	40	47	29	3	1		17	3		167
14	55	33	18	1		1	24	19	1	45
15	60	47	20			6	8	59	6	189
16	80	171	50			4	1	37	4	577
17	100	380	180			7	1	13	7	663
18	90	370	200			1		11	1	456
19	70	98	70					8		190
20	5	17	20			1		1	1	54
21	1	2	18							7
22	1	1								2
23										3
24										4
25										6
26										4
27										3
28										1
29										1
30										1
31										1
∑	1662	4148	2190	134	155	486	256	155	553	3561

Table 1: Length-frequency data of Decapterus russelli from September 2013 to November 2014 in the northern part of the Arabian Sea.

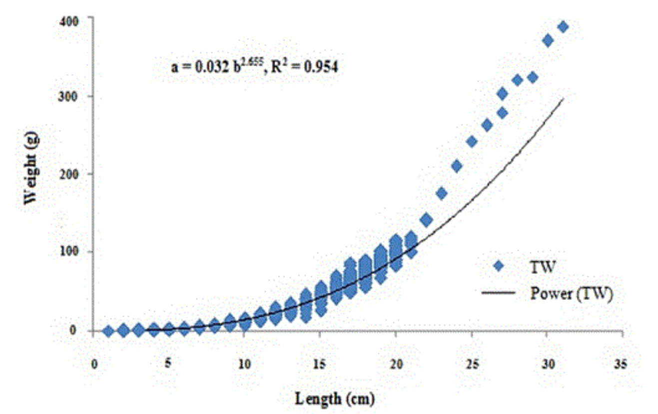

Figure 2: The Length-weight relationship of both sexes combined of *D. russelli* length and weight ranging from 1 to 31 cm (FL) and 0.5 to 400 g.

Growth parameters

A total of 13,300 length frequency distribution data was used to estimate the growth parameters by ELEFAN method. The von Bertalanffy growth parameters for *D. russelli* was estimated as L_∞=32.55 cm (FL) and K=0.750 per year (Figure 4). The t0 value was calculated by equation of Pauly as t_0=-0.678 per year. The R_n (goodness of fit) was estimated to be at 0.220 with ELEFAN-I method, Pauly [26].

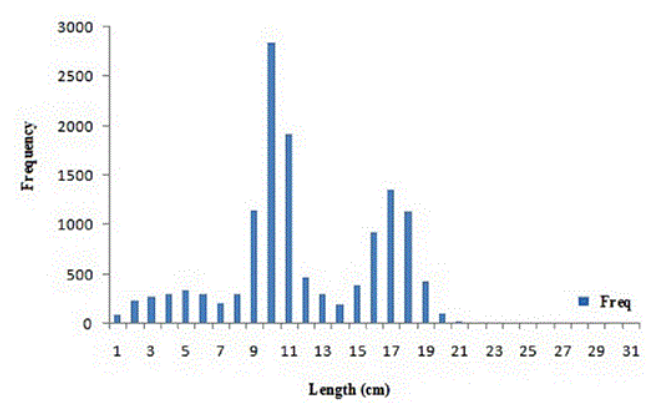

Figure 3: Length frequency distribution (n=997) ranging from 1 to 31 cm (FL) and the dominant length frequency range from 9 to 18 cm.

Mortality rate parameters

Applying the length converted catch curve analysis VBGF growth parameters (L_∞=32.55 cm (FL) and K=0. 750 per year) as the input value for the estimation of the mortality parameters of Z=3.84 per year of the total mortality (Z) estimates and it was estimated at 95% confidence interval (CI=3.11-4.58) (Figure 5). The value of natural mortality (M) was calculated as M=1.42 per year using annual average sea surface temperature (SST) 27°C. Thus, fishing mortality was calculated as F=Z-M=2.422 per year and exploitation ratio (E) was selected from F/Z=0.630 per year.

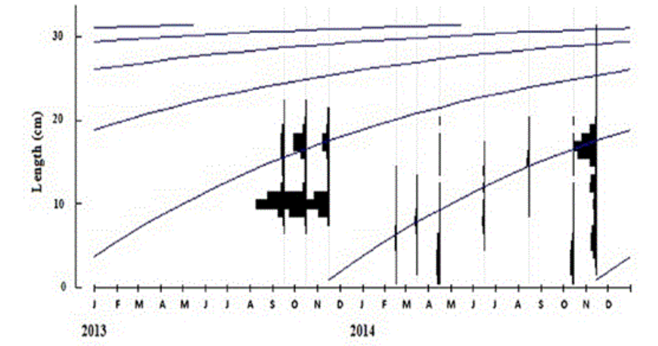

Figure 4: The total length, von Bertalanffy growth curve in this study during 2013-2014 estimated (L_∞=32.55 cm and K=0.750 year-1, t_0=-0.678).

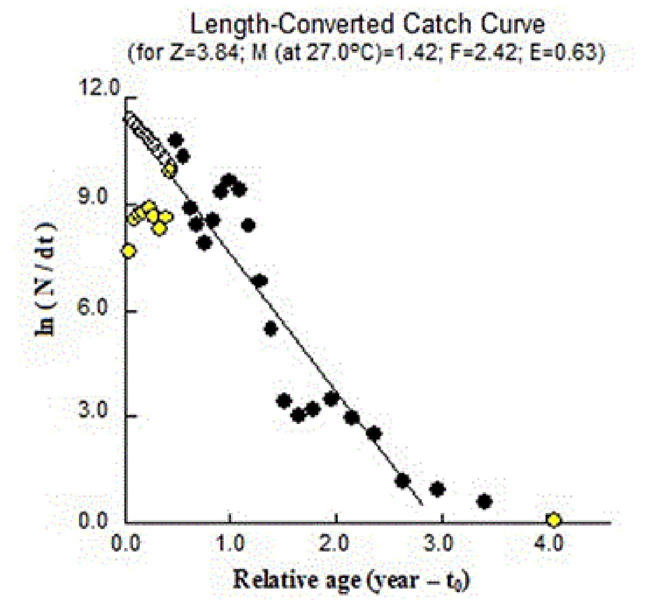

Figure 5: A Length converted catch curve analyzed for *D. russelli* using input value of VBGF growth parameters (the von Bertalanffy growth).

Biological reference points

The yield per recruit analysis representing, when the t_c was assumed to be 1, the maximum frequency F_{max} was estimated at 0.9 and $F_{0.1}$ was at 0.85 (Figure 6); therefore $F_{current}$ 2.422 per year was greater than the $F_{0.1}$ and F_{max} (Figure 1). The stock of D. russelli in marine waters of Pakistan severely overfished. Using [34] biological reference point F_{opt} M was 1.42 per year. The current fishing mortality obtained 2.422 per year was higher than the reference points obtained in Pakistan waters for the *D. russelli*.

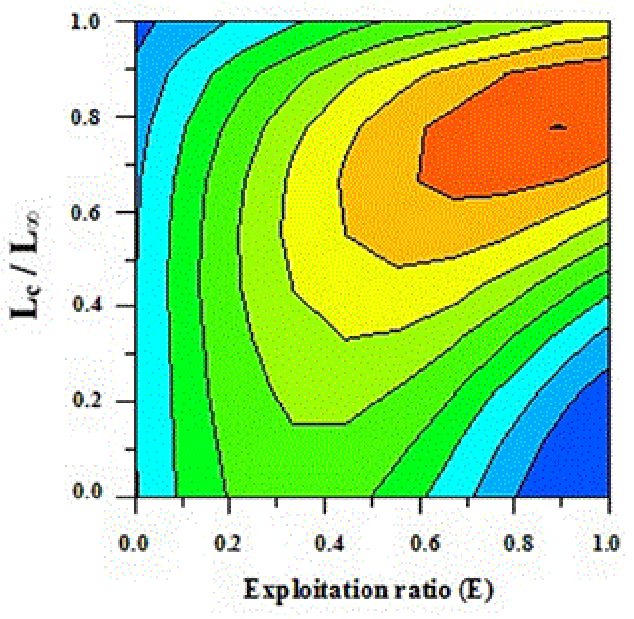

Figure 6: Yield per recruit contour map of from Pakistani waters during 2013-2014.

Growth performance index

Growth performances indices asymptotic length (L_∞) and asymptotic weight (W_∞) were Φ'=2.900 per year and Φ=0.170 per year were carried out for *D. russelli* from marine water of Pakistan during 2013-2014, respectively.

Beverton-Holt Y/R analysis

Von Bertalanffy growth model was used to estimate the asymptotic length growth factors such as asymptotic length and growth coefficient L∞=32.55 cm (FL) and K=0.750 per year by the equation of $L_t=L_\infty$ (1 - exp (- k [t - t_0]))respectively. The value of the time t, t0 is the hypothetical age t0=- 0.678 when the length of the virtual age is considered zero. Value of t0 was estimated by the empirical formula of Pauly [26].Log_{10} (-t_0)=- 0.3922 - 0.275 Log_{10} L_∞- 1.038 Log_{10} K.

Discussion

The Indian scad is one of the most important small pelagic fishes supporting the commercial fishery in Pakistan. This species has a high market demand locally due to its cheaper price relative to other pelagic fishes. Despite its significant contribution to the fishery and economic value, there are no adequate data pertaining to this species in north Arabian Sea. This study was undertaken to investigate the population dynamics and fishery of the *Decapterus russelli*. The objectives of the present study were to establish the population parameters and fishery demographics towards management practices by providing significant input in decision making for sustainable management of the fish stocks.

Length weight relationship

Length-weight relationship was mostly used for the fish growth and stock assessment [35]. The weight ratio between the lengths of the fish is very significant for the biology of fishes, Le Cren [24].

The slope values of b for *D. russelli* of both sexes combined were estimated in the present study at a=0.0323, b=2.66 with R^2=0.954 from Pakistani waters during 2013-2014. The slope b values range is from 2.5 to 3.5. The values higher than 2.5 shows that fish has isometric growth, whereas if fish has slop b values lower than 2.5 it may be considered that fish has allomatric growth [25,36]. Present value b show that fish have isomateric growth from Pakistani waters. The present study results were compared with previous studies in Table 2. The slope b values from Yemen, Gulf of Aden and Red Sea was 2.033 and 2.167 were lower than the present study [37]. While the b values from lagoon, New Caledonia was 2.948 [38], 2.963 in New Caledonia [39], in Indonesia Tegal"s water 2.879 [40] and 2.989 in Vizhinjam, India [41], which were found to be close to the current study. On the contrary, the b value 3.000 in java Sea, Indonesia [42], 301.5 Philippines [43], and in Sofala bank, Mozambique 3.026 [44], was high than the current study However, the overall b values from different part of the world is within the range of present study (b=2.66) conducted from Pakistani waters.. Small difference in the b values, may be because of seasonal variations, environmental parameters and sample collection, or, number of individuals examined in the study, the range of the length observed to be different during the study [35].

Reference	Research area	A	b	R^2
Al Sakaff and Esseen, 1999	Gulf of Aden and Red Sea	0.11	2.033	0.9 9
Al Sakaff and Esseen, 1999	Gulf of Aden and Red Sea	0.08	2.167	0.9 7
Letourneur et al., 1998	lagoon	0.01	2.948	0.9 9
Kulbick et al., 2005	New Caledonian	0.01	2.963	0.9 9
Burhanuddin et al., 1983	Tegal	0.01	2.97	-
Sreenivasan., 1981	Vizhinjam	0.02	2.989	-
Widodo., 1988	Java Sea	0.01	3	0.9 6
Ronquillo., 1975	Philippines	0.01	3.015	-
Brinca et al., 1983	Sofala Bank	0.01	3.026	-
Reuben et al., 1992	east coast	0.01	3.111	-
Gjøsaeter and Sousa., 1983	Guimaras Strait	0.01	3.12	-
Gjøsaeter and Sousa., 1983	Sofala Bank	0.01	3.121	0.8 6
Reuben et al., 1992	south-west coast	0.01	3.136	-
Reuben et al., 1992	north-west coast	0.01	3.207	-
Present study 2015	Pakistan	0.03	2.66	0.9 5

Table 2: A comparative study of length weight relationship parameters of *Decapterus russelli* from the different regions of the world.

Growth parameters

Length frequency distribution data were used to evaluate VBGF parameters, namely the asymptotic length (L_∞), growth rate (K), the growth performance index (Φ ') and imaginary or hypothetical age (t_0). The present study results were compared to the previous studies from different regions (Table 3). The asymptotic length (L_∞), growth rate (K) and growth performances indices for asymptotic length (Φ ') were calculated at 19.4, 0.75 and 2.45 from northern Arabian Sea, Pakistan, respectively [45]. The values of L_∞ and Φ ' were lower than the present study while the value of K was close enough. The L_∞, K and Φ ' values from Jave Sea, Indonesia were 28.4, 0.90 and 2.86 correspondingly [42] 30.0, 0.54 and 2.69 from Manila bay, Philippines [46], 32.2, 0.86 and 2.95 from Central area, Malaysia, Bogdanov [47], were estimated by ELEFAN methods (Table 3) and were close to the present study (32.55, 0.750 and 2.900). In Palawan, Philippines the values of L_∞, K and Φ ' were 33.7, 0.36 and 2.69 [46], L_∞ was higher and values of K and Φ ' were lower Due to the correlated parameters [48], a higher K value is normally associated with a lower L_∞ value. Differences shown in Table 3 may be because of the sampling procedure, variety of data, and the differences in their lifestyle and ecological characteristics of fish [49].

Resource	Locality	l∞	K	t0	Φ'
Iqbal., 1991	Northern Arabian Sea	19.4	0.75	-	2.45
Reuben et al., 1992	east coast	22.1	0.71	-	2.54
Reuben et al., 1992	south-west coast	24.8	0.78	-	2.68
Reuben et al., 1992	Northwest coast	29.9	0.45	-	2.6
Pauly., 1978	Manila Bay	23.3	1.13	-	2.79
Murty., 1991	Kakinada	23.2	1.08	-0.08	-
Prathibha and Shanbhogue., 2005	Karnataka coast	23.2	0.7	-0.16	-
Jarzhombek., 2007	north area	23.5	1.1	-	2.78
Isa., 1987	Penang	24	0.81	-	2.67
Isa., 1987	akarta Bay (Seribu Island)	27	1.15	-	2.92
Isa., 1987	Perlis	27	1.01	-	2.87
Jaiswar et al., 2001	Mumbai (Bombay) waters	24	1.42	-	2.91
Suwarso et al, 1995	Java Sea	24.5	0.95	-	2.76
Suwarso et al., 1995	Java Sea	25.2	1.08	-	2.84
Gjøsaeter and Sousa., 1983	Sofala Bank	24.8	0.56	-0.1	2.54
Ingles and Pauly., 1984	Palawan	26	0.73	-	2.69
Ingles and Pauly., 1984	Nansha Island	26	0.52	-	2.55
Ingles and Pauly., 1984	Java Sea (Seribu Island)	26.6	0.95	-	2.83
Ingles and Pauly., 1984	Manila Bay	30	0.54	-	2.69
Ingles and Pauly., 1984	Palawan	33	0.45	-	2.69
Chen., 2003	Vizhinjam	26	0.19	-	2.1
Dwiponggo et al., 1986	Idi, Malacca Strait	26	0.9	-	2.78
Dwiponggo et al., 1986	Palawan	26.9	0.69	-	2.7
Dwiponggo et al., 1986	Manila Bay	27	0.8	-	2.77
Sreeenivasan., 1982	Vizhinjam	26	0.185	-0.5	-
Sousa., 1992	Jakarta Bay (Seribu Island)	27	1.18	-	2.93
Sousa., 1992	Sofala Bank and Boa Paz	27.3	0.68	-	2.7
Rodriguez and Sousa., 1988	Mozambique	27.8	0.57	-0.18	2.65
Rodriguez and Sousa., 1988	Mozambique	27.9	0.56	0.18	2.64
Widodo., 1988	Java Sea	28.4	0.9	-	2.86
Bogdanov and Jarzhombek., 2004	central area	28.4	0.56	-	2.65
Bogdanov and Jarzhombek., 2004	north area	28.4	1.08	-	2.94
Bogdanov and Jarzhombek., 2004	central area	32.2	0.86	-0.04	2.95
Balasubramanian and Natarajan., 2000	Vizhinjam	29	0.8	-0.04	-
Jabat and Dalzell., 1988	Camotes Sea	33.7	0.36	-	2.61
Padilla., 1991	Guimaras Strait	33.7	0.65	-	2.87
Lavapie-Gonzales et al., 1997	Camotes Sea	35.1	1.4	-	3.24
Present study., 2015	Pakistan	32.55	0.75	-0.67	2.9

Table 3: Evaluation of current growth parameters of *Decapterus russelli* from different parts of the world.

Growth parameters were estimated by using the non-parametric method ELEFAN, which is mostly used for analyzing length frequency of fish, which is essentially ad-hoc and not dependent on convention of parameters of direct subgroups. Therefore, it makes only feeble assumptions about the dissemination of the size of the cohort. The length of each cohort model is fixed lying on a curve described by the model of growth as von Bertalanffy growth model, so it makes a powerful assumption of growth, Pitcher [50].

Mortality rate

The length-converted catch curve analysis method was used with input values of VBGF growth rate parameters for *D. russelli*. These values were matched up with the earlier work in various regions of the world, respectively (Table 4). The overall mortality rate was estimated showing only the dark circles in Figure 5. The value of the mortality rate is shown in Table 5 and Figure 7, where the total mortality rate was observed as the highest mortality in March 2014, while during November 2014 showed lowest mortality.

Source	Area	Z	M	F	E
Murty., 1991	Kakinada	6.65	1.9	4.75	0.71
Jaiswar et al., 2001	Mumbai	7.75	2.63	5.1	0.66
Manoj Kumar., 2007	Malabar	3.79	2.08	1.71	0.49
Debabrata Panda et al., 2012	Mumbai	4.61	1.81	2.8	0.61
Nalini et al., 2011	Mumbai waters	6.66	2.1	4.56	0.68
Reuben et al., 1992	East coast of India	2.83	1.35	1.48	0.52
Reuben et al., 1992	N. W. coast of India	2.85	0.83	2.02	0.71
Reuben et al., 1992	S. W. coast of India	3.88	1.26	2.62	0.68
Present Investigation., 2015	Pakistan	3.84	1.42	2.42	0.63

Table 4: Compare mortality parameters from Pakistani waters in 2013-2014 with other studies from different fields and areas of the world.

Sampling month	Z	M	F	E	95% CIZ	R2
Sep-13	5.88	1.42	4.46	0.76	3.41-8.34	0.738
Oct-13	5.64	1.42	4.22	0.75	2.67-8.61	0.613
Nov-13	8.39	1.42	6.97	0.83	0.59-16.19	0.604
Feb-14	6.72	1.42	5.3	0.79	5.27-8.16	0.945
Mar-14	12.66	1.42	11.24	0.89	7.16-18.15	0.911
Apr-14	9.84	1.42	8.42	0.86	6.86-12.82	0.827
Jun-14	7.17	1.42	5.75	0.8	4.63-9.70	0.841
Aug-14	6.74	1.42	5.32	0.79	3.38-10.11	0.931
Oct-14	4.99	1.42	3.57	0.72	2.66-7.32	0.563
Nov-14	2.83	1.42	1.41	0.5	1.89-3.77	0.748

Table 5: Instantaneous rates of mortality rates based on monthly data using the length converted catch curve analysis for *Decapterus russelli.*

In general the mortality values in Table 4 were higher compare to the present study; total (Z), natural (M), fishing mortality (F) and exploitation ratio from India Mumbai were 7.75, 2.63, 5.1 and 0.66 respectively [51]. The Z, M, F, and E values were also higher in different parts of India like Kakinada, Mumbai and Malabar Table 4 [12-14,52,53], compared to present study 3.84, 1.42, 2.42 and 0.63 respectively. While lower mortality rate values were found from east coast of India and the northwest coast of India [53]. The different mortality values from different part of the world maybe different countries have different demand of this species or maybe some ecological and environmental factors effecting on the mortality of fish, Gulland [34] noted that the exploitation rate should be lower than 0.5, while Patterson [54] describe that the exploitation rate should be maintained at 0.4 it the exploitation values exceeds 0.4 than it should be assumed that stock is overexploited state. According to Gulland [34] and Petterson [54] recommendations it should be concluded that the stock of *D. russelli* from Pakistani waters is in stress and overexploited state. Because of the current fishing rate 2.422 per year revealed higher exploitation rate than the biological reference points.

Biological reference points $F_{0.1}$ and F_{max}

Characteristically $F_{0.1}$ and F_{max} are two biological reference points (BRP), used in fisheries management around the world, which is based on the information of age and the length of the structure data and depends on the executive advice for improved management [29]. $F_{0.1}$ is defined as the rate of fishing mortality on a slight increase in yield per recruit (YPR) which is 10% of that F_0 and F_{max} is the mortality of fish, which is the highest YPR to be achieved [29] (Figure 7). Output of yield per recruit (YPR) analysis pointed out that when the tc was assumed to be 1, the maximum frequency F_{max} estimated was to be at 0.9 and $F_{0.1}$ was at 0.85; therefore $F_{current}$ 2.422 per year was greater than the $F_{0.1}$ and F_{max}, respectively. The stock of *D. russelli* in marine waters of Pakistan found to be severely overfished. Using the [34] biological reference point F_{opt} M obtained was 1.42 per year. The current fishing mortality was 2.422 per year much higher than the biological reference points in Pakistan waters.

It can be concluded from this study that the population parameters and the stock of *D. russelli* showed overexploitation in the northern parts of the Arabian Sea coast of Pakistan. In the present study, the estimated value of the current fishing mortality F_c=2.422 per year was higher than the biological reference points ($F_{0.1}$=0.85 and F_{max}=0.9) [55]. Marine resources of Pakistan are fully accessible without restrictions, with lacking actual administration and planning. The current study reflected that the stock of Indian scad is overfished [56-60]; we would recommend that some management action should be taken to reduce the fishing efforts in Pakistani waters. Sustainable fisheries management measures for this species should be observed during closing season in Pakistan to protect broods stock especially during the monsoon. Thus, fisheries managers need to take rapid action on these issues, so that our fish resources can thrive with more and set unshakable advantage for the national economic growth.

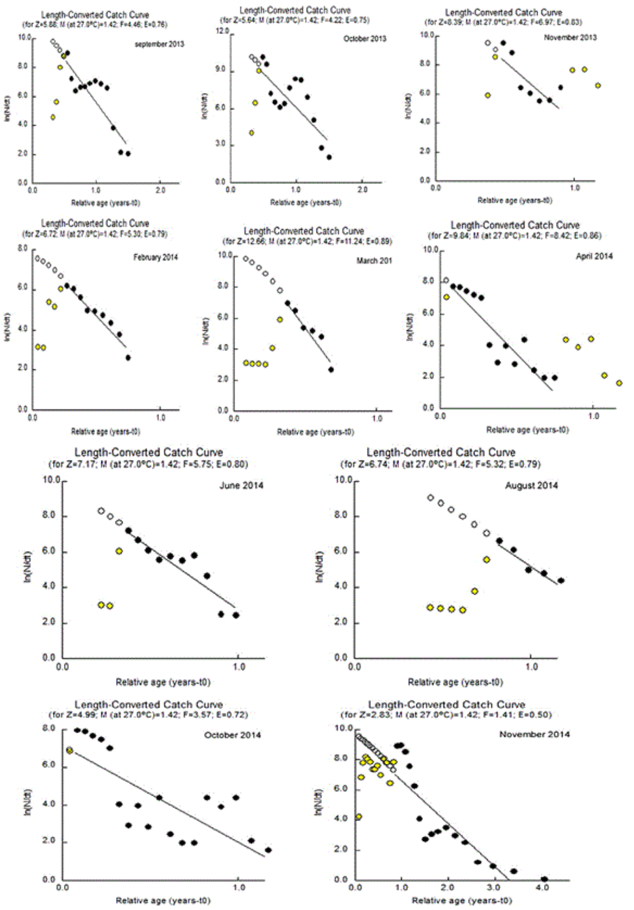

Figure 7: Length - converted catch curves for *D. russelli* from the monthly catch curve where the slope of the regression line catch curve.

Conclusion

The present study results showed that the stock of *D. russelli* fishery from Pakistani waters in overexploited state. Monitoring of the population numbers and harvest levels of this species is needed. To maintain the stock of this fishery the scientists and fishery managers have to work together for better fishery for coming future. In the light of present findings we may suggests that fishing activities must be controlled by trawl mesh size, discard of bycatch and proper check and balance of fishing and non-fishing seasons. Fishing boats must be registered under controlled authorities. Completely ban period we may suggest during peak breeding season that could save juveniles. Marine protected areas must be declared to save the fish nursery grounds. We also suggest further detailed studied maybe conducted like egg per recruit analysis for better stock management.

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